LOI for a Study of a LANNDD of 100 kTon at DUSEL/Homestake

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and the Pisa and Granada Collaborations

4.1 Search for Proton Decay to 10^{35} Years

The detection of $p \to K^+\bar{\nu}$ would seem to be the key channel for any SUSY model. This channel is very clear in liquid argon due to the measurement of the range and detection of the decay products. We expect very small background events at 10^{35} nucleon years for this mode (refer to ICARUS studies).

4.2 Solar Neutrinos and Supernova Neutrinos Studies

The major solar neutrino process detected in liquid argon is $\nu_e + {}^{40}Ar \to {}^{40}Ar + e^-$, with Ar* de-excitation giving photons with subsequent Compton events. The same process is useful for supernova ν_e detection – the expected rate for the solar neutrinos is ≈ 123,000 per year. For a supernova in the center of the galaxy with full mixing there would be ~ 3000 events - no other detection would have these many clear ν_e events.

4.3 Atmospheric Neutrino Studies

By the time LANNDD is constructed it is not clear which atmospheric neutrino process will remain to be studied. However this detector will have excellent muon, hadron and electron identification as well as the sign of $\mu^\pm$ charge. This would be unique in atmospheric neutrino studies. The rate of atmospheric neutrinos in LANNDD will be (50 kTon fiducial volume):

CC ν_e events: 4800/year

CC ν_μ events: 3900 ÷ 2800/year (depending on the neutrino mixing).

There would also be about 5000 NC ν events/year. We would expect about 25 detected ν_τ events / year that all would go upward in the detector.

240
Pages

Proton Stability in Grand Unified Theories, in Strings and in Branes

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Abstract

A broad overview of the current status of proton stability in unified models of particle interactions is given which includes non - supersymmetric unification, SUSY and SUGRA unified models, unification based on extra dimensions, and string-M-theory models. The extra dimensional unification includes 5D and 6D and universal extra dimensional (UED) models, and models based on warped geometry. Proton stability in a wide array of string theory and M theory models is reviewed. These include Calabi-Yau models, grand unified models with Kac-Moody levels $k > 1$, a new class of heterotic string models with Spin(10) gauge group in the visible sector, models based on intersecting D branes, and string landscape models. The destabilizing effect of quantum gravity on the proton is discussed. The possibility of testing grand unified models, models based on extra dimensions and string-M-theory models via their distinctive modes is investigated. The proposed next generation proton decay experiments, HyperK, UNO, ICARUS, LANNDD (DUSEL), and LENA would shed significant light on the nature of unification complementary to the physics at the LHC. Mathematical tools for the computation of proton lifetime are given in the appendices. Prospects for the future are discussed.

In order to generate neutrino mass in these theories we have to add 15_H Higgs (See for example [211]) or the right handed neutrinos. In this case we have only the operators O_I^{B-L} (Eq. 13), and O_{II}^{B-L} (Eq. 14) contributing to the decay of the proton. Let us study the prediction for proton decay in a $SU(5)$ theory with $Y_U = Y_U^T$. In this case we have $U_C = UK_u$, where K_u is a diagonal matrix containing three phases which gives [46]:

$$\sum_{l=1}^{3} c(\nu_l, d_\alpha, d^C_\beta)^*_{SU(5)} c(\nu_l, d_\gamma, d^C_\delta)_{SU(5)} = k_1^4 (V^*_{CKM})^{1\alpha} (K_2^*)^{\alpha\alpha} (V_{CKM})^{1\gamma} K_2^{\gamma\gamma} \delta^{\beta\delta} \tag{168}$$

In this case the clean channels to test the scenario, are [46]:

$$\Gamma(p \to K^+ \bar{\nu}) = k_1^4 \left[A_1^2 |V^{11}_{CKM}|^2 + A_2^2 |V^{12}_{CKM}|^2\right] C_1 \tag{169}$$

$$\Gamma(p \to \pi^+ \bar{\nu}) = k_1^4 \left|V^{11}_{CKM}\right|^2 C_2 \tag{170}$$

~~where~~

$$C_1 = \frac{(m_p^2 - m_K^2)^2}{8\pi m_p^3 f_\pi^2} A_L^2 \left|\alpha\right|^2 \tag{171}$$

$$C_2 = \frac{m_p}{8\pi f_\pi^2} A_L^2 \left|\alpha\right|^2 (1 + D + F)^2 \tag{172}$$

where the notation is as in Appendix G. Here we have two expressions for k_1, which are independent of the unknown mixing matrices and the phases. Thus it is possible to test $SU(5)$ grand unified theory with symmetric up Yukawa matrices through these two processes [46]. These results are valid for any unified model based on $SU(5)$ with $Y_U = Y_U^T$. Similar tests can be investigated for other gauge groups. Specifically a discussion of the tests for the gauge groups $SO(10)$ and flipped $SU(5)$ is given in Appendix G.

5.5 Proton decay in flipped $SU(5)$

In the previous section we have shown the possibility to make a clear test of realistic grand unified theories with symmetric Yukawa couplings through the

Further, a majority of non-supersymmetric extensions of the Georgi-Glashow $SU(5)$ model yield a GUT scale which is slightly above 10^{14} GeV. Hence, as far as the experimental limits on proton decay are concerned, these extensions still represent viable scenarios of models beyond the SM. Region of M_X excluded by the experimental result is also shown in Figs. 6 and 7. The plots of Fig.(6,7) exhibits that it is possible to satisfy all experimental bounds on proton decay in the context of non-supersymmetric grand unified theories. For example in a minimal non-supersymmetric GUT [211] based on $SU(5)$ the upper bound on the total proton decay lifetime is $\boxed{\tau_p \leq 1.4 \times 10^{36}}$ years [212].

6 Unification in Extra Dimensions and Proton Decay

6.1 Proton decay in models with 5D

In this subsection we discuss proton decay in higher dimensional theories specifically in theories with one extra dimensions. Theories with extra dimensions have a long history beginning with the work of Kaluza and Klein in the nineteen twenties [222, 223, 224, 225]. More recently interest in theories with extra dimensions emerged with the realization that string theories could allow for low scale compactifications which removes the rigid relationship that exists between the string scale and the Planck scale in the weakly coupled heterotic strings [226]. Thus, in the context of weakly coupled Type I string compactifications the string scale can be quite low [227, 228] and there has been much work in model building along these lines [229, 230, 231, 232] and important constraints have been placed on the size of such dimensions from experiment [233, 234, 235]. An interesting phenomena in such theories is the power law evolution of the gauge coupling constants [236, 237, 238, 239] which allows for a meeting of the coupling constants at a low scale although in such a scheme the unification of the gauge couplings is not a prediction of the model but rather an accident. The second more serious issue concerns stability of the proton. This is so because if one wishes to formulate unified models with low scale extra dimensions then dimension five and dimension six baryon and lepton number violating operators are suppressed only by the inverse powers of a mass order a TeV which would lead to disastrous proton

Many Calculations give

$\tau_{p \to K^+ \bar{\nu}} \lesssim 10^{35}$ y

which LANNDD can reach!

Figure 4 – DUSEL Homestake site.

- Detector efficiency and construction costs:

  Large volume monolithic configuration: to maximize the fiducial-to-instrumented liquid argon volume ratio, to minimize the surface-to-volume ratio (minimum heat input, minimum cryostat wall out-gassing) and to minimize the number of wires and electronic channels.

  Long electron drift (~ 5m): to minimize the number of drift regions and of the related wire chambers (drawbacks: use of 250-300 kV noiseless high voltages, argon purity at 10-$50 \cdot 10^{-12}$ p/p O_2 equivalent levels).

  Ultra low-noise economic front-end electronics: also to partially compensate the drawbacks of the previous point.

  Cryostat built with UHV standards (clean materials and assembly techniques) *with design allowing vacuum before filling with liquid argon*: to allow for the required argon purity

- Running costs:

  Optimized thermal insulation: cryostat insulation based on lattice double walls with vacuum in-between, to minimize the liquid nitrogen consumption to compensate heat inputs. See Table 1 and Ref. 1[1].

- Underground site and safety:

  Tectonic study and survey: to understand the realistic size of an underground hall suitable for hosting the detector and the yard for its construction/assembling.

Shaft for elevators (for pre-assembled large size detector details, liquid argon and liquid nitrogen supply dewars), *ventilation and argon/nitrogen exhausts.*

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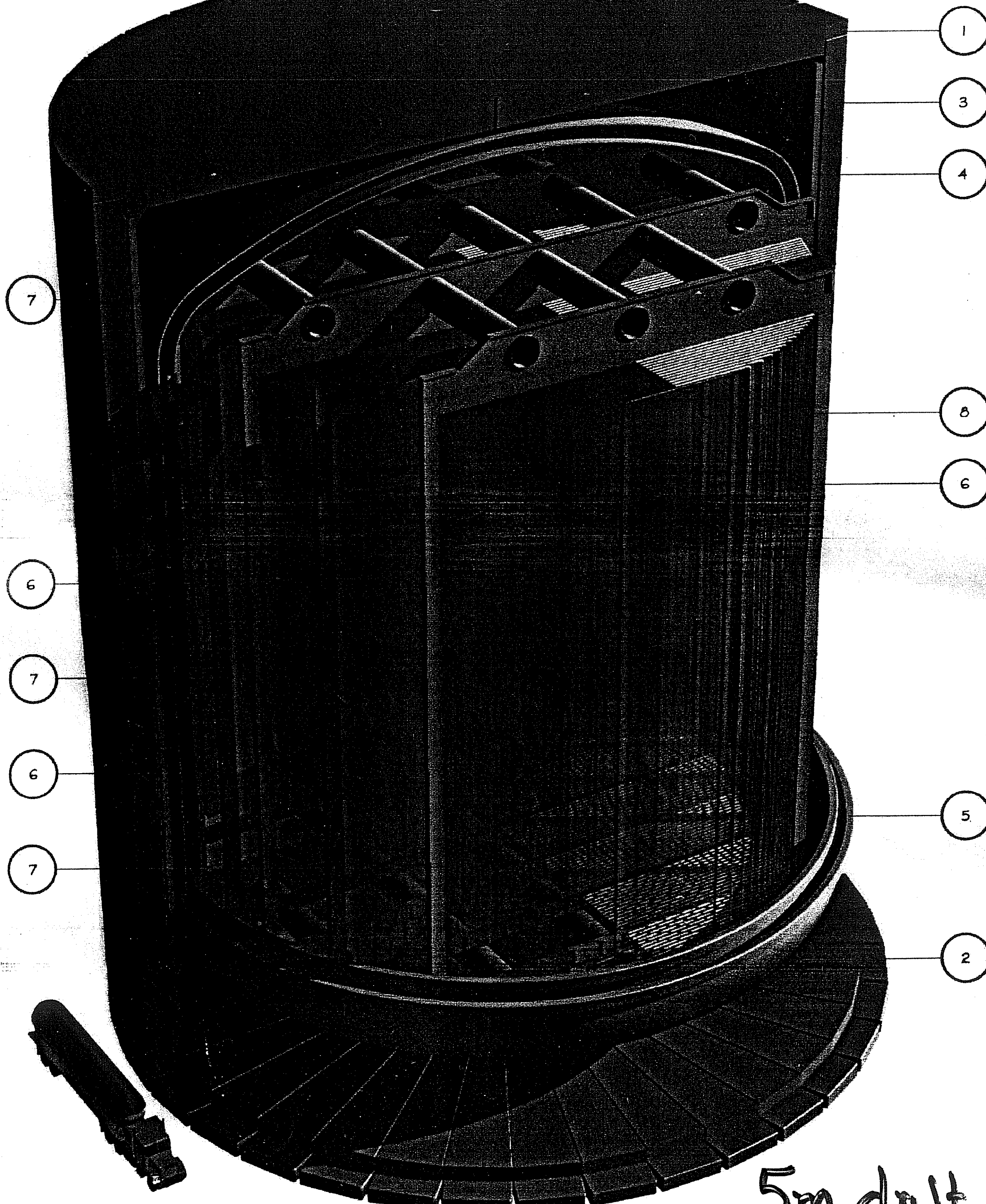
[1] D.B. Cline and F. Sergiampietri, "A Concept for a Scalable 2 kTon Liquid argon TPC Detector for Astroparticle Physics", http://arxiv.org/abs/astro-ph/0509410

1 - TOP END CAP IRON YOKE
2 - BOTTOM END CAP IRON YOKE
3 - BARREL IRON RETURN YOKE
4 - COIL
5 - CRYOSTAT

- LANNDD -
70KT

6 - CATHODES (N° 5)
7 - WIRE CHAMBERS (N° 4)
8 - FIELD SHAPING ELECTRODES



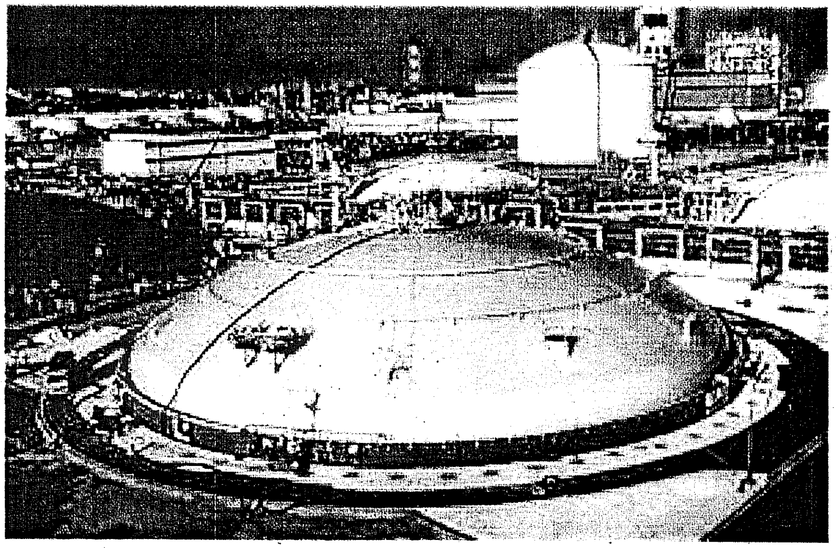
5m drift
assumed

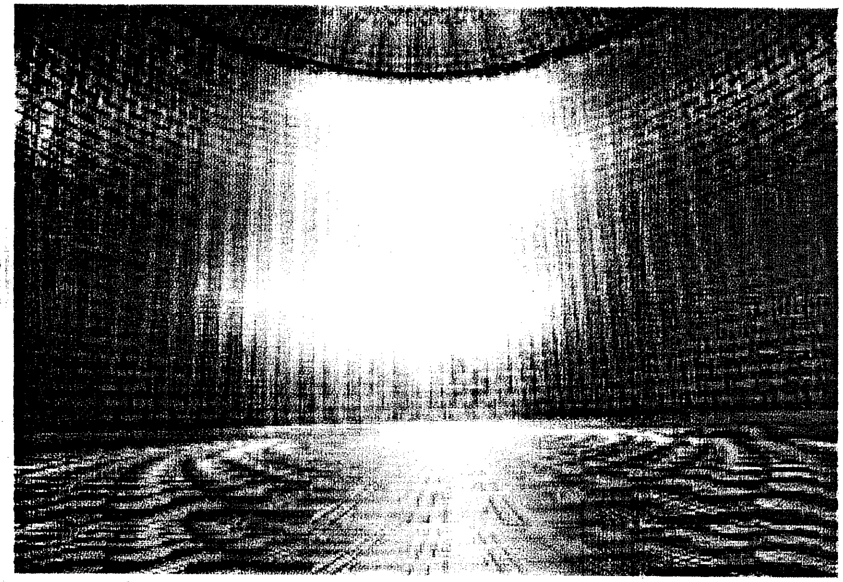
LANNDD
Liquid Argon Neutrino and Nucleon Decay Detector

F. SERGIAMPIETRI - August 2000

VERY LARGE CRYOGENIC TANKS ROUTINE AROUND THE WORLD

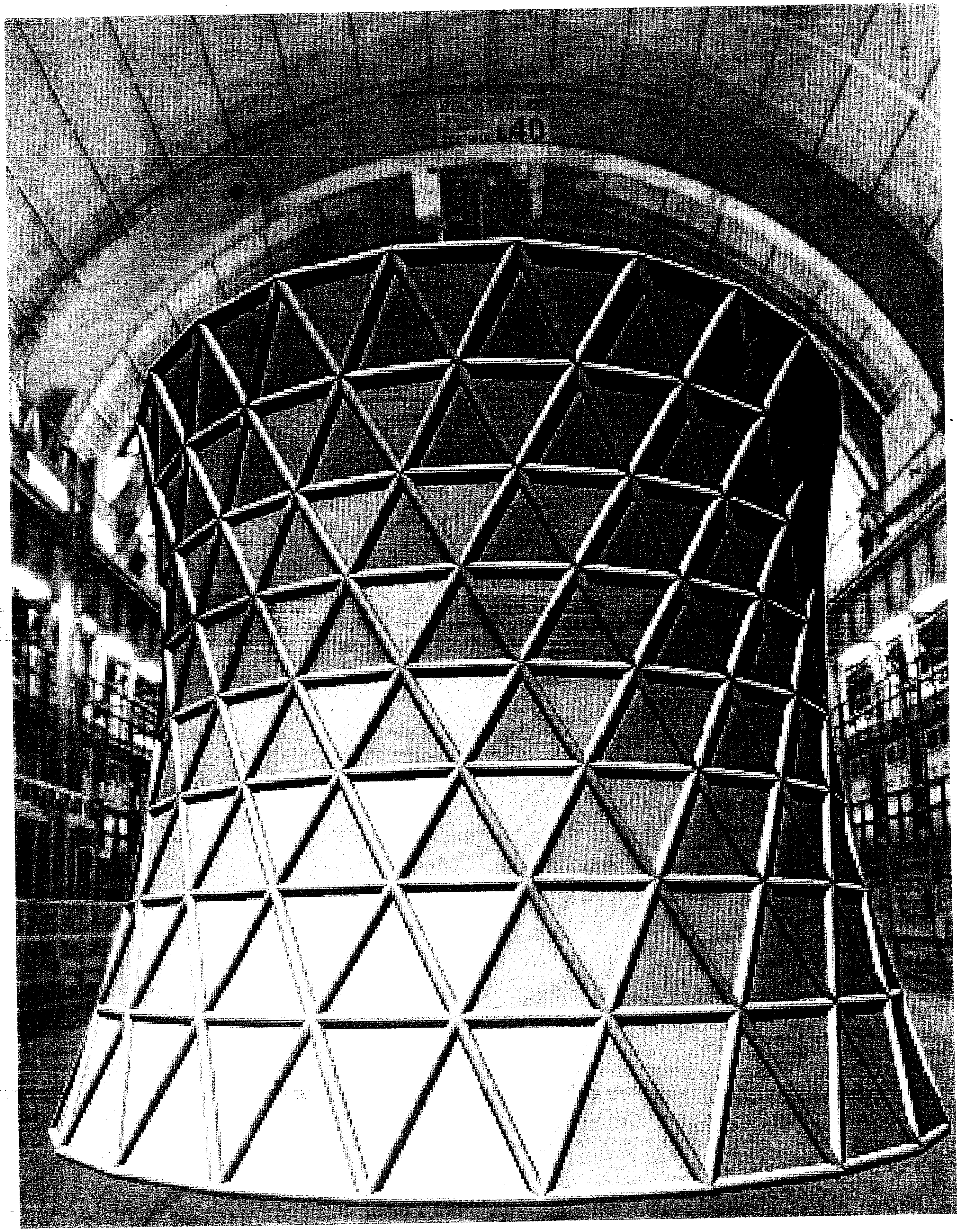
- Large modules ($\gtrsim 100$ kton) can be built using technology of liquid methane storage. (Total cost of a 100-kton detector is estimated to be \$200M.)





- Detector is continously "live" and can be "self-triggered" using pipelined, zero-suppression electronics.
- Operates at the Earth's surface with near zero overlap of cosmic ray events.
- Detector is compatible with operation in a magnetic field.

NEW CONCEPT FOR LANDD



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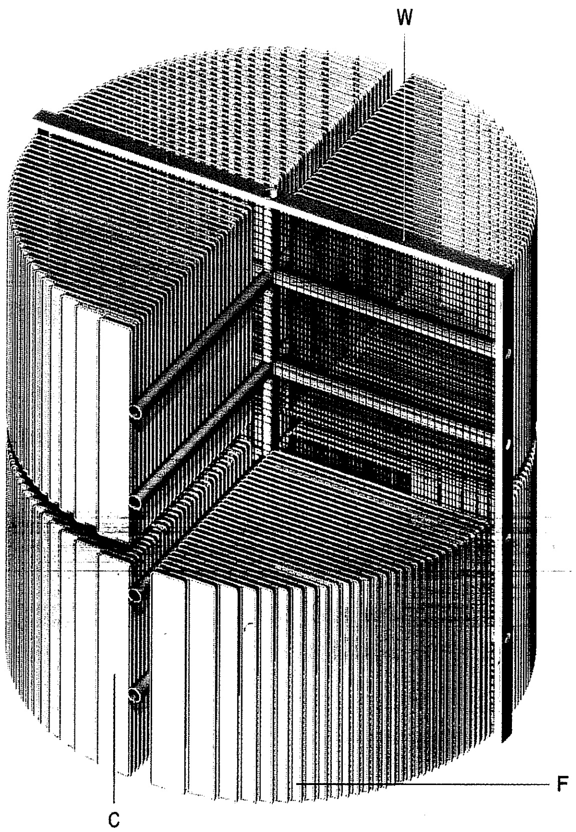

Figure 1 – The inside detector, with one of the top quarters not shown. W: wire chambers; F: field-shaping electrodes; C: cathodes. The inner reinforcing cross is also indicated.

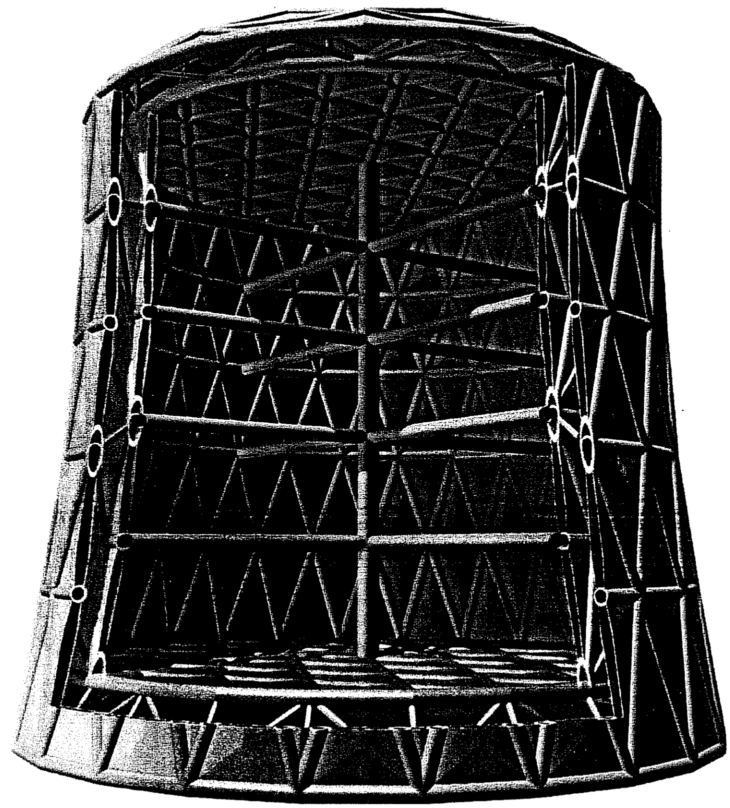

Figure 2 – Cutaway view of the proposed cryostat design. The inner cross-structure is indicated for an eventual increase of the inner vessel rigidity.

Table 1

Active LAr				
mass [kTon]	**2**	4	10	100
diameter = height [m]	**12.2**	15.5	20.9	45
volume [$10^3 \cdot m^3$]	**1.43**	2.9	7.2	71.6
Inner vessel				
diameter = height [m]	**13.0**	16.5	22.3	48.0
outer surface [m^2]	**797**	1'591	2'906	13'464
volume [$10^3 \cdot m^3$]	**1.7**	3.5	8.7	86.9
Outer vessel				
diameter [m]	**15.0**	19.0	26.0	55.5
height [m]	**16.0**	20.3	27.4	59.1
Total heat input[2] [kW]	**1.6**	3.2	5.8	27.0
LN_2 consumption [m^3/day]	**1**	2.1	3.7	17.3
Number of wires/el. Channels	**8320**			

[2] Unitary heat inputs lower than 1 W/m^2 are reachable with vacuum and super-insulation layers. We assumed 2 W/m^2 to take into account residual conduction heat inputs through signal cables, mechanical supports and spacers.

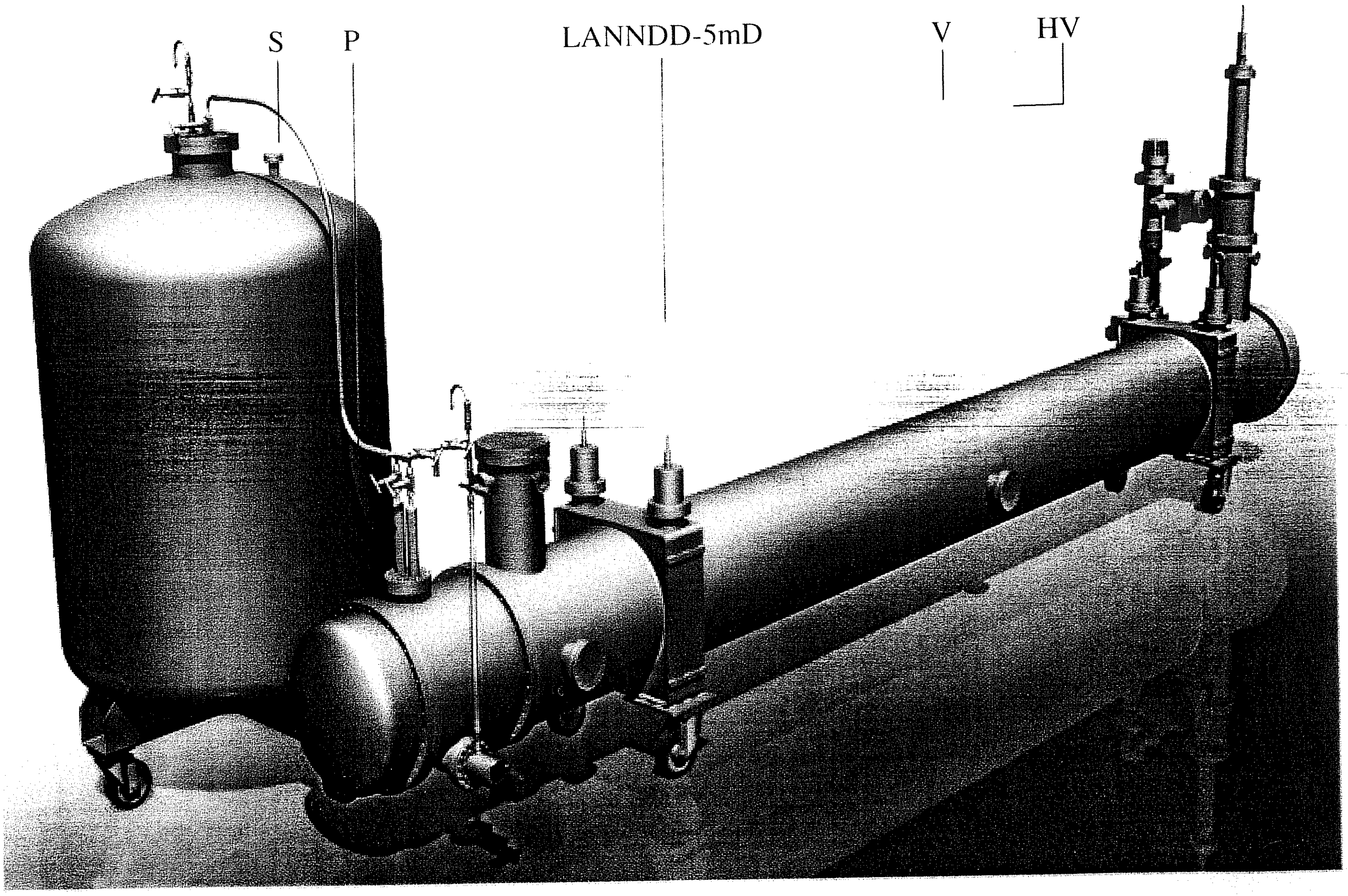

Figure 3 – The LANNDD-5mD detector with the liquid argon storage tank (**S**), the integrated purification system (**P**), the high voltage feedthrough (**HV**) and the insulation vacuum pumping group (**V**).

Propose to move to Homestake in 2008 for Tests and Experiments